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www.publish.csiro.au/journals/ijwf *International Journal of Wildland Fire*, 2007, **16**, 673–678

A fuel treatment reduces fire severity and increases suppression efficiency in a mixed conifer forest

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Abstract. Fuel treatments are being implemented on public and private lands across the western United States. Although scientists and managers have an understanding of how fuel treatments can modify potential fire behaviour under modelled conditions, there is limited information on how treatments perform under real wildfire conditions in Sierran mixed conifer forests. The Bell Fire started on 22 September 2005 on the Plumas National Forest, CA. This fire burned upslope into a 1-year old, 158-ha mechanical fuel treatment on private land. Prior to coming into contact with the fuel treatment, the main fire ignited spot fires 400 feet (122 metres) into the treated area. Overall, this fuel treatment resulted in: (1) increased penetration of retardant to surface fuels; (2) improved visual contact between fire crews and the Incident Commander; (3) safe access to the main fire; and (4) quick suppression of spot fires. This treatment was relatively small and isolated from other fuel treatments but resulted in decreased severity, suppression costs and post-fire rehabilitation needs, leading to cost savings for local public and private land managers.

Additional keywords: Plumas National Forest, thinning.

Introduction

Fuel treatments are being widely implemented on public and private lands across the western United States (Stephens and Ruth 2005). Over 4.5 million ha of hazardous fuel reduction and landscape restoration activities have been implemented since federal fiscal year 2000 (Healthy Forests Report 2005). The stated goals of these treatments are to: '(1) directly reduce wildfire threats to homes and communities that are adjacent to or within the wildland–urban interface (WUI); (2) treat areas outside of the wildland–urban interface (non-WUI) that are at greatest risk of catastrophic wildland fire – these high priority, non-WUI treatments move towards restoring fire to its historical role – and (3) maintain previous treatments to ensure resiliency to catastrophic wildland fire and implement activities that are in line with other long-term management goals' (Healthy Forests Report 2005).

Although scientists and managers have an understanding of the principles of fuel reduction (Graham *et al*. 2004; Agee and Skinner 2005; Peterson *et al*. 2005) that can modify potential fire behaviour under modelled conditions (Scott and Reinhardt 2001; Stephens and Moghaddas 2005), there is limited information on how treatments perform under real wildfire conditions in Sierran mixed conifer forests (Fites and Henson 2004). Public land managers are often tasked with designing projects to meet 'desired future conditions' for fuel treatments, though there is limited information on what these conditions should be across a broad range of site classes and forest types. Although several fires have been directly documented by fire managers burning or spotting into recently established fuel treatments (Hood 1999; Beckman 2001), relatively few of these events are formally studied to determine the effects of the fuel treatment on fire behaviour and severity in Sierran mixed conifer forests.

The purpose of the present paper is to document one example of how a fuel treatment influenced fire behaviour and enhanced suppression efficiency in a mixed conifer stand within the WUI. Second, this paper quantifies a stand structure that functioned as an effective fuel treatment under the weather conditions described. This case study is not intended to be a pre or post comparison of stand structure, modelled fire behaviour, or predicted severity.

Methods

Study site

The study area is in northern California on the Beckworth Ranger District of the Plumas National Forest, ~1 mile (1.6 km) south of Highway 89 at Lee Summit. The treatment described was established on private timberlands owned by the Soper-Wheeler Co. The treatment unit is located within the 2.4-km extended WUI of Spring Garden, a Community at Risk (PCFSC 2005; Callenberger and Lunder 2006). The parcel is bordered on two sides by untreated National Forest Land (Figs 1–3). The fuel treatment was established on the top and north side of a ridge, immediately above the Middle Fork of the Feather River. The dominant aspect of the treated area is north-facing with an average slope of 11 percent. The area within the treatment is classified as a Dunning Site Class II (Dunning 1942), meaning at 50 years, dominant tree height will average 23 m. Data available from the timber harvest plan and associated inventory plots were used to establish pretreatment stand conditions. After treatment, three 0.04-ha fixed radius plots were established along a transect within the area affected by spot fires. These plots were measured within 2 months of the fire.

 10.1071/WF06066 1049-8001/07/060673

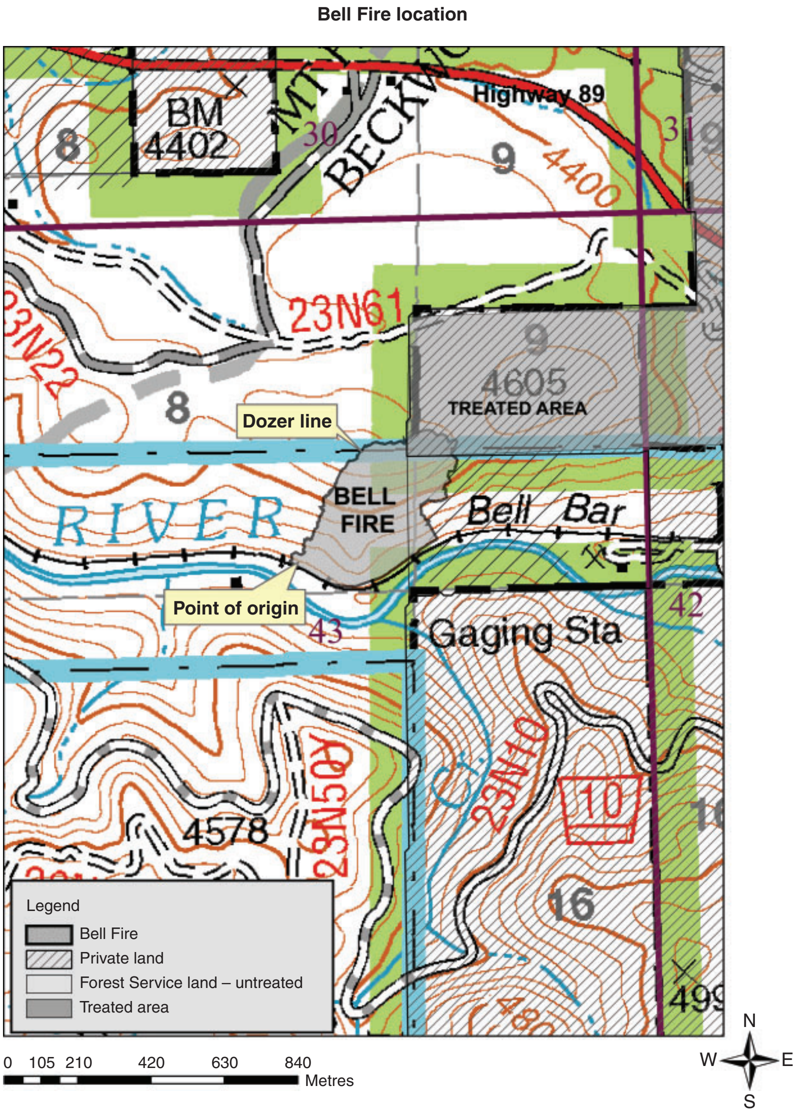

Fig. 1. Study area is located north-east of the Bell Fire point of origin, and is surrounded by untreated public lands. Fire began on railroad and progressed north-east towards treated area.

Treatment prescription

The forest type is Sierran mixed conifer forest dominated by Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco), incense cedar (*Calocedrus decurrens* [Torr.] Floren.), ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.), sugar pine (*Pinus lambertiana* Dougl.), white fir (*Abies concolor* Gord. & Glend.), and California black oak (*Quercus kelloggii* Newb.). Prior to treatment, stand basal area was 59 m^2 ha^{-1} per acre and tree density was 1181 trees ha^{-1}. Stands were thinned in the summer of 2005 under a selection harvest (CDF 2003) using a leave-tree mark. Biomass and sawlog material were removed mechanically using a whole tree harvest system. Submerchantable material and tops were chipped at the landing and hauled to a local cogeneration plant. An average of ~8.6 m^3 ha^{-1} of saw logs and 8.1 bone dry tonnes of biomass per hectare were removed from the project area (P. Violett, Soper-Wheeler Co., pers. comm.).

General fire information

The Bell fire was reported at 1213 hours on 22 September 2005 (Table 1). The fire was accidentally ignited by railroad activity along the tracks immediately downhill from and below the project area (Fig. 1). Relative humidities and peak wind speeds averaged 18 percent and 16 km h^{-1}, respectively, during the burning period between 1200 and 1600 hours (Table 2).

Results

Post-treatment stand structure

Mechanical treatments resulted in a relatively open stand with vertical and horizontal separation of ladder and crown fuels (Fig. 2). Average forest structure and fuel loadings for the treated stand are reported in Table 3. Though surface fuels were not treated after mechanical harvest, residual 1-, 10-, and 100-h fuels

Fig. 2. Treated stands on private land (foreground) and untreated stands on Forest Service land (background). Property line follows edge of thinned area.

combined averaged 11.9 t ha^{-1} (Table 3). Fuel depth averaged 3.6 cm (Table 3). There was no evidence of brush on the plots at the time of measurement (Table 3).

Predicted and actual fire behaviour and suppression tactics

The fire moved quickly up a steep, south-facing hill from the point of origin to the ridgeline, which was also the boundary of the fuel treatment. At the ridgeline, flame lengths from torching trees were observed as high as 9.2 m above the tree canopy. Trees on the slope between the ridgeline and the point of origin generally had over 75% scorch. This level of scorch was observed on trees over 50 cm in diameter. From the point the fire came into contact with the fuel treatment to ~60 m into the fuel treatment, the level of scorch decreased. Similar patterns of scorch were observed in the Cone Fire at Blacks Mountain Experimental Forest (Skinner *et al*. in press).

Up to four spot fires were ignited within the fuel treatment area. These fires ignited directly in activity fuels left after the harvest. Predicted flame lengths and mortality for these spot fires are shown in Table 3. Observed flame lengths on these spot fires were less than 0.6 m and there was little evidence of scorch on trees larger than 25-cm diameter at breast height (DBH).

The actions taken for suppression of the fire are based on discussions with on-scene personnel (L. Craggs, Plumas National Forest, pers. comm.) and summarised here. Hand crews hiked into the base of the fire along the railroad tracks, anchored their fireline and continued constructing lines up the east and west fire flanks. The Incident Commander (IC) and two bulldozer transports could access the main fire from Highway 89, along a dirt road, and directly through the treated area. From this point, the IC could also easily locate established spot fires. Owing to relatively low rates of spread and flame lengths, the decision was made to line spot fires using the bulldozer. After lining the spot fires, the bulldozers then cut a line between the approaching fire front, the untreated USDA Forest Service (USFS) land, and the treated private property. The dozer line between the main fire and untreated USFS land was completed before the main fire reached the ridge. When the fire reached the main ridge and the fuel treatment, torching stopped though direct scorch still occurred within the first 60 m of the treatment. During the active suppression period, aerial retardant was being delivered to the area between the main fire and both the private treated area and the untreated USFS property. Finally, an 11 000-L water truck and a portable water tank were brought forward into the treated area

Fig. 3. Closer view of untreated stands (background) immediately adjacent to treated stands (foreground).

Table 1. General fire information

Fire name	Bell Fire
Location	Plumas National Forest, Beckworth Ranger District: T 24N, R 8E, Section 9
Elevation range (m)	1258 to 1404
Burning index on day of fire	61
Energy release component on day of fire	57
Report date and time	22 September 2005 at 1213 hours
Containment date and time	22 September 2005 at 1900 hours
Control date	22 September 2005 at 1800 hours
Cause	Ignition from railroad activity
Final size	35 acres (14.2 ha)

and used in conjunction with engines to extinguish spot fires and for 'mop-up'. Mop-up included extinguishing smouldering fires in stumps and logs after the main fire had been extinguished. Mop-up activities extended into the next day.

Discussion

Fuel treatment effects on fire behaviour

The treatments utilised principles of fuel reduction including thinning from below and use of whole tree harvest (Agee and Skinner 2005). Although no further treatment of activity fuels generated by the harvest were completed, residual, post-treatment fuel loads and arrangement resulted in observed flame lengths in spot fires of less than 2 feet (0.6 m). These low flame lengths in conjunction with relatively high crown base heights resulted in limited observed scorch in spot fire areas at the time of measurement. Percentage crown volume scorched was up to 75% immediately at the southern edge of the fuel treatment where the fire came in from, and decreased to less than 10% within 60 m of this edge. Spot fires were easily lined and allowed to burn out while suppression resources were concentrated on the main fire flanks. The combination of fuel treatment location on a ridge and north side of the ridge in conjunction with post-treatment stand structure resulted in decreased flame lengths, resulting in lower overall fire severity within the treatment area.

Table 2. Weather parameters during active burn period on 22 September 2005
Weather taken from the Quincy remote access weather station (#40910), located ~16 km north-west of the Bell Fire

Time hours	Relative humidity %	Dry bulb temperature °C	10-h fuel moisture %	Fuel temperature °C	Peak windspeed km h^{-1}	Wind direction degrees from N
1200	25	23	8.9	23	9.7	260
1300	18	29	8.7	39	9.7	144
1400	15	30	8.0	38	22.5	224
1500	14	29	7.5	37	20.9	243
1600	17	28	7.2	34	27.4	267
1700	21	26	7.1	27	19.3	256
1800	23	24	7.0	26	17.7	256
1900	31	19	7.0	17	11.3	259

Table 3. Post-treatment stand and fuel characteristics; predicted fire behaviour and percentage mortality ($n = 3$ plots)
Standard deviation not shown for model outputs; diameter at breast height, DBH

Attributes	Post-treatment average	Standard deviation
Stand characteristics		
Trees per hectare	181.1	121.8
Average tree height (m)	22.1	3.8
Canopy base height (m)	9.2	2.7
Quadratic mean diameter (cm)	39.6	9.1
Basal area per acre (m^2 ha^{-1})	23.7	10.2
Canopy cover (%)	36.3	11.5
Stand density index	130.3	35.6
Tree species composition (%)		
Douglas fir	41	33
Incense cedar	21	6
Ponderosa pine	20	15
Sugar pine	12	14
White fir	6	10
Black oak	0	0
Surface fuel characteristics		
Litter and duff (metric t ha^{-1})	40.8	30.7
1-, 10-, 100-h combined	11.9	8.7
1000-h sound	4.3	3.8
1000-h rotten	1.3	2.0
Fuel depth (cm)	3.6	3.0
Canopy cover (%)	40.8	30.7
Predicted fire behaviour and tree mortality		
Predicted flame length (m)	1.0	–
Torching index (km h^{-1})	>64	–
Crowning index (km h^{-1})	>64	–
Predicted tree mortality (percent)		
Trees 2.5 to 25 cm DBH	60	–
Trees 25 to 51 cm DBH	14	–
Trees 51 to 76 cm DBH	5	–

Fuel treatment effects on suppression activities

In terms of suppression tactics, the treated area established a safe access point that could be used to move equipment and other resources towards the head of the main fire. The fuel treatment allowed crews to drive almost directly to the main fire and leave vehicles parked in a safe area. Had the treated area not been in place, equipment (engines, water truck, and bulldozers) and fire crews would not have been able to safely access the main fire to take direct action. This would have resulted in the use of indirect suppression methods, leading to increased suppression efforts when compared with the direct control methods utilised. The relative openness of the stand allowed the IC to maintain visual contact with equipment and personnel. In addition, this openness allowed greater penetration and coverage of aerial retardant to surface fuels. Based on visual observations, substantially more retardant reached surface fuels in the treated area than on the untreated USFS lands. In untreated areas, retardant primarily ended up in the upper tree crowns where it was less effective at containing and reducing surface fire spread.

The overall results of this treatment were decreased suppression intensity and increased suppression effectiveness. This in turn resulted in decreased damage to the stand due to suppression activities and direct scorch. In turn, these factors decreased the relative total cost of suppression and follow-up rehabilitation. The total cost to suppress, mop-up, and rehabilitate dozer lines on this fire was US$64 000. Had the fire not been contained at the small size, fire managers may have had to use indirect containment tactics, including burning out and additional fire line construction. These additional actions and associated and rehabilitation costs could have increased total fire costs substantially.

Conclusion

It is important to emphasise that fuel treatments are not designed to stop all fires – the purpose of the present paper is not to make this assertion. Fuel treatments are typically designed to decrease flame lengths, fire spread, and ideally, reduce landscape-level fire severity (Finney 2001; Stratton 2004). Often, they are used in conjunction with suppression resources (Agee *et al.* 2000). This is an important point to bring out when communicating the potential effectiveness of fuel treatments with the public. Not all fuel treatments will modify fire behaviour all the time in all vegetation types or weather conditions. Breaking up vertical and horizontal continuity of live and dead fuels in this particular case reduced passive crown fire within treated areas. Decreased flame lengths and visual contact in treated areas allowed more direct suppression methods to be employed. It is difficult to say how big the fire would have been without treatments in place or if indirect methods were used but based on discussions with personnel on scene, suppression intensity and cost were decreased by these treatments. If the fire had become established in the untreated areas, suppression intensity, cost, and follow-up rehabilitation would have likely been higher.

Fire managers should be able to easily document their direct experiences with fire behaviour within established fuel breaks. Fire fighters are often the only ones to regularly witness 'real time' fire behaviour within fuel treatments. Their direct observations, in conjunction with post-burn measurements of burn severity, are critical in determining when and where fuel treatments are most effective at reducing fire size and severity. These observations also help define modifications to future fuel treatments that can make them more effective. This is imperative considering the limited funds available for establishing fuel treatments in comparison with the number of acres that need to be treated. If documented and available for public access, these observations may inform the research community of sites for possible future studies of fuel treatment effectiveness as well as inform and refine current hypotheses used for these studies. This information will help provide the necessary feedback for changing and improving practices through adaptive management.

Acknowledgements

Thanks to Paul Violett and the Soper-Wheeler Co. for allowing access to their land and records for the present study. Special thanks to Larry Craggs, Fire Management Officer, and Ryan Southwick, Dozer 2 Operator, both from the Mount Hough Ranger District on the Plumas National Forest. Their eyewitness experiences of this fire were essential in conveying the story of what happened as seen by the people who were there as it burned.

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Manuscript received 18 May 2006, accepted 6 September 2007